rest, believed by many to be closely related to present ignorance of the laws of fatigue and the best modes of applying them in practise, has emphasized the importance of this branch of research.—*British Medical Journal.*

SCIENTIFIC BOOKS

Constructional Data for Small Telescope Objectives. Calculated at the National Physical Laboratory. By T. Smith and R. W. Cheshire. 4to. Pp. 32. *Additional data for the construction of small telescopes objectives.* By the same authors. Prepared at the request of the Director General of Munitions Supplies. 4to. Pp. 82. London, Harrison and Sons, 1915 and 1916. Price, 2s. 6d. and 5s.

During the war every possible stimulus and aid was offered to manufacturers by the English government no less liberally than by our own, and of course some years earlier. The present volume is intended to save the manufacturer of small telescopes a large part of the time and expense that would be consumed in perfecting his models. British glass factories, aroused to the emergency, had succeeded in producing new varieties and a large quantity of optical glass, duplicating in feverish haste inventions evolved at leisure by German scientists and artisans during the previous thirty years. But the grinding of lenses and their combination into effective sets for binoculars, gun-sights, range-finders and photographic cameras can not be begun until protracted mathematical calculations are finished. Years of preliminary study have often gone into the making of an improved objective. One must conjecture, design, calculate and compare. Obviously, carefully systematized records of previous studies would save labor: cooperation is economy. These tables mark a new application of this principle. Glass factories supply, with a list of available melts, their indices of refraction and dispersion. By the tables one can decide quickly upon the comparative merits of doublets made from those materials.

Objectives are usually made of from two to six separate lenses. Each component by itself gives a defective image. Rings of blue or red encircle each bright object, and in place of points of light there appear hazy circles or fantastic comet-like shapes. If at the center of the field a picture is fairly good, the parts toward the edge are distorted. To improve such crude images, at least two lenses must be used in combination. Accordingly data are here given for suitably matched two-lens objectives, one lens of crown glass, the other of flint glass, so proportioned as to eliminate at least two of the so-called aberrations, or defects of the image. The figures relate to six kinds of crown glass (a seventh in the supplement) and six kinds of flint glass. The selection of typical sorts is not made at random, nor at equal intervals in the whole range of possibilities, but near what we may call, borrowing a statistical term, "accumulation" points of the catalogue list. To suit each of six sets of conditions the proper dimensions are found for every combination of one kind of crown with one kind of flint, so that every table contains 36 entries.

The first set of tables (A) eliminates color and spherical aberration; not, of course, for all kinds of light and for objects at all possible distances, but for two different wave lengths of light and for objects at a distance so great that the rays striking the glass are practically parallel ("object at infinity"). To the removal of color from the image corresponds an algebraic equation of the first degree between the focal lengths of the two lenses, both considered as "thin"; while that for spherical aberration is of the third degree in the curvatures, or reciprocals of the radii of the spherical surfaces of the lenses. But when the two lenses are to be in contact, and their contiguous surfaces are exactly alike so that they may be cemented, the third degree equation for that common radius is reduced by one degree, to a quadratic. For this equation then there are two solutions, and so two tables of curvatures. Indeed all the pairs here tabulated are cemented lenses. Since two of the four spherical surfaces have equal radii for any desired focal length, there re-

main only two unknowns to be determined by conditions which will eliminate aberrations. For the first, our authors select color—chromatic aberration. The second condition in one case that for spherical aberration; in another, for coma; and in a third case, for equality of three radii instead of merely two. Evidently therefore this publication, though valuable as a first, is only the first among a large number of desirable thesauri for optical designers.

Of two solutions for the same physical condition, equally correct mathematically, one may prove in practise far superior. Tables *A* and *B* enable us to compare these two, both free from spherical aberration, thirty-six samples of each. To the cautious tyro, and also, it appears, to the expert, it seems better to select surfaces of small curvature where possible; although in microscopes, as Abbe demonstrated, such counsel is often misleading. Taking as unit the focal length of the combined lenses, Table *A* shows radii of curvature varying from 0.2977 to 5,000 or, for the cemented surface alone, from 0.2977 to 0.4671. The second solution, or Table *B*, shows radii for this middle surface of from 0.1705 to 0.3495. On this account therefore Table *A* gives the more useful patterns. An additional table gives for each type the amount of coma left uncorrected, which averages nearly the same for *A* as for *B*.

Both *A* and *B* are calculated for the arrangement of crown lens preceding, flint following. The reversed arrangement is provided for in Tables *E* and *F*, and these call for radii which are individually and on the average considerably smaller, curvature therefore greater; but in *E*, the coma remaining in the system is somewhat reduced. Other tables are for forms where three radii are equal and the fourth surface nearly flat, so that the cost of grinding might be lessened even though the telescope would be less efficient. These last are accompanied by an exhibit of the residual amount of both spherical aberration and coma. Two further tables promise freedom from coma, with stated amounts of uncorrected spherical aberration.

So far, it has been assumed that the thickness of the lenses is so small as to be negligible. Of course the diameter that is needed for a particular purpose may cause a thickness which is far from negligible, especially in types having one or more fairly large curvatures. To allow for this, the authors fix arbitrarily a "standard thickness" of one-fortieth the focal length for a convex lens, one eightieth for a concave, and furnish for these standards thicknesses tables of two sorts. The first shows how much the focal length is diminished by standard thickness when one uses the radii taken from a thin-lens table, and the second shows by what amount the curvature of the fourth surface (the most nearly flat) may be modified to restore the focal length to its intended value, unity.

Such an alteration of one surface is however only a make-shift, as is seen from the later tables (1916), "Additional data," etc. To alter the curvature of a single one of the four surfaces disturbs not only the focal length, but also the precise balance of both the aberrations which are already eliminated. The authors recommend it indeed only when the focal length is to be short. Otherwise it is necessary to change slightly all three curvatures from the 1915 tables. Very full information is given as to the amount of change. First they give factors for interpolation when either index differs slightly from that for which the earlier tables were computed. Then back to this table are referred, in the next following series, the effects of standard thickness upon chromatism. Namely, the corresponding change to be made in the ratios of indices for flint and crown is stated, so that by two tables the changes of curvatures can be found. Next comes the effect upon spherical aberration resulting from standard thickness, and last, the necessary changes in curvatures to correct that error. But it is recommended that when two kinds of aberration simultaneously become serious in amount, the curvatures be computed entirely *de novo*, since the errors are not wholly independent. Such computation is of course greatly facilitated by knowl-

edge of any approximate values for the radii; and this constitutes one of the chief reasons for expecting these tables to prove generally serviceable.

The authors deserve the thanks of optical computers further, in particular, for their care in testing results by trigonometrical calculations. Judging from more than a hundred such verifications, they inform us, the small errors in the approximate values of spherical aberration occur only in the fourth decimal place, so that they would hardly influence the specifications to be given to the mechanician. The data in the first tables run to three decimal places.

Of major significance are the graphs, pages 80 and 81, showing the performance of typical lenses of the various types at different apertures. Group *A* makes quite the best showing. The final page, with some general conclusions, may well be read first.

American readers will have noticed already, from certain reports published by the Bureau of Standards, that projects not wholly dissimilar to this have been under consideration, and are already partially realized, for lightening the arduous labor of finding satisfactory first approximations in definite types of lens design.

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SPECIAL ARTICLES

ELECTROLYTES AND COLLOIDS

THE effect of ions on the physical properties of proteins is one of the most interesting chapters of colloid chemistry. The work on this topic quoted in the textbooks of colloid chemistry suffers from two sources of error, namely, first, that the effect of the hydrogen ion concentration is generally ignored, and second, that the effect of the nature of ions on the physical properties of proteins is often ascertained in the presence of an excess of an electrolyte. Proteins are amphoteric electrolytes and therefore occur in three states according to the hydrogen ion concentration, namely as: (1) protein, free from ionogenic impurities, (isoelectric protein); (2) metal proteinates, *e. g.,* sodium proteinate or calcium proteinate, etc.; and (3) protein acids, *e. g.,* protein chloride or protein sulfate, etc. For gelatin the hydrogen ion concentration defining the isoelectric point is, as Michaelis[1] first showed, about 2×10^{-5} N (or in Sörensen's logarithmic symbol pH $= 4.7$). At this hydrogen ion concentration gelatin can practically combine with neither anions nor cations of an electrolyte. When the hydrogen ion concentration becomes lower than 2×10^{-5}, *e. g.,* through the addition of NaOH, part of the isoelectric gelatin is transformed into sodium gelatinate, and the relative amount of isoelectric or non-ionogenic gelatin transformed into sodium gelatinate increases with the diminution of the hydrogen ion concentration. Sodium gelatinate can exchange its cation with the cation of neutral salts but is not (or practically not) affected by the anion of a neutral salt. When we raise the hydrogen ion concentration of gelatin solutions above that of the isoelectric point, *e. g.,* by adding HCl, isoelectric gelatin will be transformed into gelatin chloride and the transformation will become the more complete the higher the hydrogen ion concentration, until finally all the isoelectric gelatin is transformed into gelatin chloride. The gelatin-acid salts can exchange their anion with the anion of other salts but are not (or practically not) affected by the cation of other salts.[2]

While isoelectric gelatin has a minimal osmotic pressure, a minimal power of swelling, a minimal viscosity, a minimal transparency, a minimal alcohol number, etc., gelatin salts, *e. g.,* sodium gelatinate or gelatin chloride, have a high osmotic pressure, a high power of swelling, a high viscosity, etc. The writer has been able to show by volumetric analysis that the osmotic pressure, the power of swelling, etc., of gelatin increase with the relative amount of isoelectric gelatin transformed into gelatin salt.[3] The physical properties of gelatin, *e. g.,* its

1 Michaelis, L., "Die Wasserstoffionenkonzentration," Berlin, 1914.

2 Loeb, J., *J. Gen. Physiol.,* 1918–19, I., 39, 237.

3 Loeb, J., *J. Gen. Physiol.,* 1918–19, I., 237, 363, 483, 559.